Bunn & Lehman

Investigation and redesign of illuminating system of Trinity Church

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INVESTIGATION AND REDESIGN OF ILLUMINATING SYSTEM OF TRINITY CHURCH

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AND

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

CHARLES MONTGOMERY BUNN and RUEL FORREST LEHMAN

ENTITLED INVESTIGATION AND REDESIGN OF ILLUMINATING SYSTEM OF

TRINITY CHURCH

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

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INVESTIGATION AND REDESIGN

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INTRODUCTION

The past few years have seen great advancement in the art of illumination. There is, however, still room for improvement in this kind of electrical work. Many of our large and otherwise modern buildings are equipped with illumination systems, which are not only wasteful of electrical energy, but are extremely injurious to the eyesight of those who use them. In churches it is especially true that the comfort and welfare of the audience has, in many cases, been sacrificed for the sake of a beautiful piece of art which not only throws the light directly into the listener's eyes, but, by its splendor attracts his attention from the speaker. Concealed lighting is coming more and more into favor as a remedy to this fault.

The Trinity Methodist Episcopal Church of Urbana, Ill., a good print of which is shown on page 41 , is one of the new churches which has a lighting system very similar to those found in the majority of such structures. The purpose of this thesis is to make a tho-

rough investigation of the conditions now existing in this church, and to design a new system of illumination which will be free from the faults found with the present one. The former will be done by means of photometer readings taken in all parts of the main auditorium, and the latter largely by means of theoretical calculations.

DISCUSSION OF THE PRESENT ILLUMINATION

In taking up a discussion of the present lighting conditions inthis church, we will first mention those points, both favorable and otherwise, which are most noticeable in an inspection of the interior. No attempt will be made to study the illumination in the Sunday school and class rooms, the investigation being confined to the main auditorium.

With the exception of a 100 watt tungsten, installed over the choir loft since our work began, 16 c.p. carbon filament lamps are used all over the building. These are arranged as follows; nine lights evenly distributed on the side walls underneath the balcony, nine on the edge of the balcony, twelve around the side walls above the balcony, twenty four on the central chandelier, and fifteen on the arch above the choir loft. The power is supplied from a 220 volt, 3 wire system, and the lighting load in the church is very well balanced. No fault can be found with the arrangement of light on the main floor. It is sufficient for all reading purposes and is fairly well distributed all over the room. After sitting in a pew for a short time, however, the most serious objection to the present arrangement becomes painfully evident to the audience by an unpleasant burning sensation of the eyes. This is caused by the large number of light rays which fall directly upon the face no matter in what part

of the room one may be sitting. In a well arranged system, the lamps should be placed so that the eye-brows shade the eyes from all direct sources of light. To do this, a light must be placed where it cannot shine directly on the face of one of the audience unless it comes at an angle of less than 25 degrees in front of a perpendicular drawn through the eye. This 25 degrees is called the critical angle for eye-brow shading and means that all rays of light coming at less than this angle from such a perpendicular will be cut off by the eye-brow. In this respect the lights on the side walls and edges of the balcony are very well arranged, the chief offenders being the large central chandelier and the row of lamps on the arch above the choir loft. The artistic qualities and economical placing of the chandelier just mentioned cannot be questioned. Neither can it be said to throw too many direct rays of light into the eyes of one sitting on the main floor, but to a person sitting in the balcony, especially in the back central part it is most offensive. Here the lowest row of seats is only five feet below the middle of the fixture, as can be seen from the print on page 42, and the top most row is on a level with it, compelling the listener to gaze thru the large cluster of lights in order to see the speaker and choir in front.

Bad as it is, the part of the illumination system just mentioned has some redeeming features, but of the row of lights placed over the choir not this much can be said. The fifteen bare carbon lamps arranged as they are, almost directly in the line of vision of the audience, acts as a means of torture to the eyes of the listener no matter whether he sits in the balcony or on the main floor. They are neither efficient nor artistic. For lighting the city streets during the holiday season, they might be effective, but for the purpose for which they are now used, no good excuse can be found. If

the globes were frosted and reflectors were used, the present condition would be somewhat improved, but even this could not be called a satisfactory means of lighting this part of the church. Since the beginning of this investigation a 100 watt tungsten lamp has been suspended from the arch and arranged to hang about ten feet above the floor. This helps the illumination in the choir loft, but does not do away with the evils of the lights above.

The last defect to be noticed is the absence of light on the stairs leading from the main floor to the balcony. Here the proper placing of one lamp would greatly increase the illumination and make the upper part of the church much easier to reach.

The above are the faults of the present system. Our next step will be to investigate the problem more thoroughly by means of the photometer readings. Following this we will endeavor to design a method of illuminating the church, which will be free from the many faults now seen, and, at the same time, be so practical that it will be adopted in the near future.

DISCUSSION OF DATA OBTAINED.

By means of the data and curves, many interesting things are brought out concerning the present lighting system. The horizontal illumination on the main floor is seen to be very satisfactory, ranging from .3 candle feet in the back part of the room to .97 candle feet under the chandelier. On the balcony, however, this illumination is very low, especially in the back central partwhere the photometer gave a reading of .098 candle feet. The average of the horizontal readings taken in this part of the church was only .2 which is much too low for satisfactory lighting. In the choir loft, owing

to the fact that the 100 watt tungsten lamp mentioned above was installed just before the readings were taken, the light was all that could be desired, ranging from .6 to 6.5 candle feet. The high values of illumination are needed here because of the fact that it it used almost entirely for reading purposes. One objection to be brought up against the results found, however, is the non-uniformity of the light distribution.

Next taking up the 45 degree readings taken in the different parts of the church, it is seen that the values vary somewhat with those found on the horizontal plane, but that they are much lower especially in some parts of the room. This brings out the important fact that the light which is for reading purposes is not the illumination on the horizontal plane, but may be much higher or lower according to the arrangement of the light sources.

The readings taken on the different vertical planes, both in the balcony and choir loft, are of such a high value as to show to some extent the greatest objection to the present system, which is the excessive amount of light shining directly into the eyes of both the choir and congregation.

METHOD OF TAKING READINGS.

The entire set of readings of the intensity of illumination in the different parts of the church auditorium was taken by means of the Sharp-Miller portable universal photometer made by Foote, Pierson and Company, New York. This instrument is essentially a hard wood box about two feet in length and having a hinged cover so that the interior is easily accessible. The comparison lamp, mounted within a circular metal housing, is moved back and forth on a platform by

means of a cord which passes around pulleys and is then attached to a drum that can be turned from the outside. The readings are taken from a translucent celluloid scale set in the side of the box, and which can be covered by a dark shutter to prevent external light from entering the interior while the lamp is being adjusted. At one end of the photometer is an elbow tube, which fits friction tight, and can be turned at any angle to receive the light and transmit it to a reversible plate. This plate can be turned so as to expose either a diffusely reflecting surface used in the measurement of candle power, or a mirror used in connection with a test plate on the end of the tube for measuring illumination. To increase the range of measurement of the instrument two absorbing screens, one transmitting 10 % and the other 1 % of the light falling upon it, are placed just back of the elbow tube. When the screens are turned so as to intercept no light the candle feet are read directly from the scale. For very high or low values of illumination, however, either one of these screens can, by means of a knurled head on the top of the box, be interposed either between the prism and the elbow tube or between the prism and the milk glass window. This arrangement was particularlyfitted for taking the readings in the church under consideration due to the fact that in most of the positions the illumination was too low to be read directly, wheras in a few places it was too high to be read with the screen between the prism and the glass plate. The screen used was the one supposed to transmit 10 % of the light. In order to determine its accuracy, a careful calibration of the same was made the results of which are shown on page 26 . From these it is seen that the light actually transmitted is 10.04 % or near enough to the maker's value to be considered as correct. All readings, pages 12 to 26 , taken directly are marked with an #. Those not indicated in

this manner were taken by using the above device, and then reducing to the true values by means of the proper ratio as determined in the calibration just mentioned. On the side of the photometer is a small adjustable resistance used to keep the voltage of the comparison lamp at the proper value. This part of the instrument was out of order, making it necessary to carry along a stove-pipe rheostat which was inconvenient to handle, but very satisfactorily performed the work expected of it. Aside from this difficulty and the few mistakes due to our inexperience in handling the photometer, it was found to be very efficient and suitable for this kind of work.

In the beginning of this investigation, two kinds of data were wanted. One of which was the light falling on a plane a few feet above and parallel to the floor, and the other was the light on the pages of a hymn book or Bible held by one of the congregation while in the act of singing or reading. The latter readings were taken with the test plate on the elbow tube of the photometer at a height of four feet three inches and turned back at an angle of 45 degrees with the horizontal. This was the result of the following assumptions;

1. Practically all of the reading and singing in this church is done by persons who are in a standing position.

2. The average height at which a book is held bya man or woman standing is four feet three inches.

For reading purposes the approximate angle which such a book should make with the horizontal is 45 degrees.

Later on in the investigation one of the most objectionable features in the present lighting system was seen to be the large amount of " glare" found in many parts of the auditorium. There was no accurate way of measuring this, but readings were taken to show

the light shining directly into the eyes, or the illumination on a vertical plane. Owing to the fact that this trouble was not so noticable on the main floor and that the time allowed was short, the readings of this kind were taken only in the balcony and choir loft. The data obtained for the horizontal and vertical illumination was taken with the photometer at the same height as was used for the 45 degree readings. This introduced little or no error and made the taking of the data much less complicated.

THE NEW DESIGN.

The first change contemplated is the removal of the large central chandelier, and substituting for it two rows of 25 watt tungsten lamps placed on the ceiling. These lamps are to be arranged in two rows as shown on page 32 , the one which extends from side to side of the church to have 16 lights placed 3 feet apart, and the row which runs lengthwise of the room to have 9 lights placed 8 feet apart. The two rows are to meet in the center of the ceiling where a large 200 watt lamp of the same shape as the others is to be placed. These ceiling lights are to have a small ball shaped bulb and a reflector which with the filament used give a distribution curve as shown on page 38 . From this drawing a good idea of the shape of the lamp itself can be had. The arrangement of the light source just mentioned, is expected to do away with many of the faults now present. Owing to the shape of the church ceiling the majority of the lights, which are in the row running from one side of the room to the other, will be invisible to the people sitting in the back central part of the balcony where so much trouble is experienced with the present system. On the other hand, the other row of lights part of

which is directly above the heads of the people in this part of the church, will serve to increase the illumination here and make reading more possible. On page 27 are some calculations which show the theoretical illumination on a point directly below the center lamp and ata height at which the photometer readings were taken. The actual light here will be greater than these results show, due to the fact that only the illumination coming from the ceiling lamps was calculated, that coming from the lights on side walls and edge of balcony being neglected. From these results it is seen that the light in the center of the room would be just as good as it is at present, and, owing to the distributed light sources, would be greatly increased on the other parts of the room this giving a more uniform illumination.

The next change to be made is the removing of the row of carbon lights on the arch above the pulpit. The system of lamps described above will serve to give sufficient light on the ceiling in this part of the church, and, owing to their arrangement and to the fact that their bulbs are frosted as will be spoken of later, no injurious effect will be had on the eyes of the audience. To properly illuminate the choir loft, and, at the same time to throw very little light in the eyes of the congregation, an art glass fixture has been designed several views of which are given on pages 39 and 40 . The advantages of this design are easily seen from these drawings. The front of the fixture extending down much further than the rear serves to throw the light back, and the grouping of the 3 32 c.p. bare carbon lights throws the rays on all parts of the choir. To get the best efficiency from this design, it should be hung about 12 feet above the floor and one foot back of the arch. This would give sufficient light on the piano music rack and would not give too high a value of illumination just below the source of the rays.

The difficulty of seeing the way up the steps leading to the balcony should be removed by placing a small 25 watt tungsten lamp on the ceiling above the landing between the two floors.

The last and most sweeping change is the substitution of frosted tungstens for the bare carbon lights now used on the side walls and edge of balcony. The frosting of these lamps reduces their life about one half, but the tungsten has a normal life of twice that of the carbon lamp thus offsetting the loss due to frosting, the great gain in efficiency and artistic qualities easily warranting the change. It is true that the tungsten lamp operates better when hung vertically, but owing to the fact that the fixtures are made to hold the lights at a very small angle from the vertical and due to the superior quality of the newer lamps of this kind, no trouble will be experienced from this source. In the art glass fixture there is no need of frosting and the lamps are held a pronounced angle from the vertical, hence it is thot advisable to use carbon lamps here.

On page 28 some calculations have been made showing the costs of both the present system and the new design. It must be understood that these estimates were made on the first cost of the lamps alone, the reflectors being considered as costing the same in each case and are therefore neglected. With the exception of the art glass fixture in the new design and the chandelier in the present system, the other equipment is the same. It is evident that the latter would be more expensive than the former hence the advantage here is with the new system. From the calculations made, the candle power required for illuminating the church is somewhat greater in the new method than in the old. This is due to the greater height at which the lamps are placed from the floor. The first cost of the lamps

now used is about $13.50, whereas in the other case it is about $42.67 This is an advantage of the present system, but when the cost of power to operate the lamps during an assumed equal life of 500 hours in each case is calculated at a normal rate of 10 cents per K.W hour, the superiority of the new design is shown. The cost in one case being $ 201.50 and in the other $ 96.00. If we add the first cost to each we have for a total cost of the present system $ 215.00 and for the same of the new method $ 138.67. If to the latter cost a reasonable loss due to the changing of one system of illuminating to the other was added, there would still be a balance in favor of the new design. It must be remembered, however, that economy, important as it may be, is not the prime requirement for a method of church illumination. The artistic qualities are of far more importance, and above all the comfort of the audience must be catered to no matter what the cost. In these respects the advantages of the new design have already been shown to such an extent that there should be no hesitation in its adoption.

PRESENT ILLUMINATION ON THE MAIN FLOOR

HORIZONTAL.

Position of Photometer.		Readings in Candle Feet.			
Section.	Number.	First.	Second.	Third.	Average.
A	1	.42	.41	.40	.410
A	2	.42	.45	.46	.442
A	3	.48	.45	.44	.454
A	4	.38	.42	.40	.400
A	5	.56	.55	.56	.555
A	6	.40	.39	.44	.410
A	7	.55	.55	.54	.547
A	8	.50	.48	.47	.481
A	9	.34	.34	.34	.340
A	10	.49	.55	.49	.510
A	11	.46	.42	.42	.433
A	12	.32	.30	.32	.313
B	1	.52	.52	.52	.520
B	2	.55	.57	.54	.552
B	3	.81	.77	.76	.777
B	4	.82	.83	.82	.823
B	5	.62	.63	.62	.623
B	6	.98	.96	.97	.970
B	7	.71	.71	.71	.710
B	8	.80	.80	.76	.787
B	9	.71	.68	.70	.695
B	10	.50	.55	.50	.517
B	11	.50	.49	.51	.500
B	12	.53	.54	.54	.537

PRESENT ILLUMINATION ON MAIN FLOOR.

(Continued)

Position of photometer.		Readings in Candle Feet.			
Section.	Number.	First	Second.	Third.	Average.
B	13	.42	.45	.46	.443
B	14	.50	.54	.48	.507
C	1	.42	.42	.39	.410
C	2	.46	.43	.46	.450
C	3	.48	.46	.48	.473
C	4	.40	.40	.40	.400
C	5	.52	.48	.52	.503
C	6	.54	.52	.52	.527
C	7	.52	.50	.52	.513
C	8	.47	.47	.47	.470
C	9	.49	.51	.50	.500
C	10	.39	.34	.34	.357
C	11	.34	.35	.34	.343
C	12	.32	.31	.32	.317

PRESENT ILLUMINATION ON MAIN FLOOR

AT 45 DEGREES.

Position of Photometer.		Reedings in Candle Feet.			
Section.	Number	First.	Second.	Third.	Average.
A	1	.28	.26	.29	.277
A	2	.41	.41	.41	.410
A	3	.41	.40	.39	.400
A	4	.33	.37	.37	.357
A	5	.43	.44	.45	.440

PRESENT ILLUMINATION ON MAIN FLOOR

AT 45 DEGREES.

(Continued)

Position of Photometer.		Readings in Candle Feet.			
Section.	Number.	First.	Second.	Third.	Average.
A	6	.50	.52	.48	.500
A	7	.50	.48	.44	.473
A	8	.28	.26	.27	.270
A	9	.32	.32	.33	.327
A	10	.35	.34	.34	.343
A	11	.196	.194	.20	.196
A	12	.154	.152	.144	.150
B	1	.54	.54	.54	.540
B	2	.56	.55	.53	.543
B	3	.71	.68	.70	.693
B	4	.62	.70	.65	.656
B	5	.62	.60	.58	.600
B	6	.60	.62	.60	.607
B	7	.47	.46	.46	.463
B	8	.48	.44	.47	.463
B	9	.31	.29	.30	.300
B	10	.28	.27	.28	.277
B	11	.33	.30	.30	.310
B	12	.41	.41	.41	.410
B	13	.36	.31	.32	.330
B	14	.35	.36	.37	.360
C	1	.35	.35	.35	.350

PRESENT ILLUMINATION ON BALCONY

HORIZONTAL.

(Continued)

Position of Photometer.		Readings in Candle Feet.			
Section.	Number.	First.	Second.	Third.	Average.
B	4	.144	.140	.138	.140
B	5	.22	.23	.24	.230
B	6	.35	.37	.36	.360
C	1	.28	.29	.29	.287
C	2	.23	.22	.21	.220
C	3	.33	.34	.36	.340
C	4	.22	.22	.22	.220
C	5	.76	.72	.78	.753
C	6	.26	.22	.23	.238
C	7	2.3	2.3	2.3	2.300
C	8	2.9	3.1	3.0	3.000
D	1	.176	.195	.20	.190
D	2	.176	.161	.16	.166
D	3	.145	.149	.146	.147
D	4	.126	.127	.126	.126
D	5	.097	.098	.098	.098
D	6	.164	.162	.163	.163
D	7	.125	.122	.123	.123
D	8	.75	.73	.74	.740
D	9	.165	.17	.16	.165
E	1	.16	.156	.155	.157
E	2	.140	.145	.143	.143
E	3	.107	.104	.105	.105

PRESENT ILLUMINATION ON BALCONY

HORIZONTAL.

(Continued)

Position of Photometer.		Readings in Candle Feet.			
Section.	Number.	First.	Second.	Third.	Average.
E	4	.123	.117	.120	.120
E	5	.092	.092	.092	.092
E	6	.126	.124	.125	.125
E	7	.085	.089	.090	.088
E	8	.132	.136	.134	.134
E	9	.20	.20	.20	.200
F	1	.17	.168	.17	.170
F	2	.23	.21	.21	.217
F	3	.17	.18	.16	.170
F	4	.29	.31	.31	.307
F	5	.22	.22	.22	.220
F	6	.22	.21	.22	.217
F	7	.50	.50	.50	.500
G	1	.22	.24	.23	.230
G	2	.24	.26	.25	.250
G	3	.17	.18	.16	.170
G	4	.29	.31	.31	.307
G	5	.22	.22	.22	.220
H	1	.28	.30	.29	.290
H	2	.27	.28	.26	.270
H	3	.48	.48	.48	.480
H	4	.30	.31	.32	.310

PRESENT ILLUMINATION OF BALCONY

AT 45 DEGREES.

Position of Photometer.		Readings in Candle Feet.			
Section.	Number.	First.	Second.	Third.	Average.
A	1	.30	.26	.25	.270
A	2	.40	.38	.38	.390
A	3	.145	.146	.14	.143
A	4	.50	.52	.54	.520
A	5	.31	.29	.32	.307
B	1	.20	.21	.20	.203
B	2	.25	.24	.24	.243
B	3	.28	.25	.26	.263
B	4	.41	.40	.41	.407
B	5	.20	.20	.20	.200
B	6	.50	.48	.49	.490
C	1	.37	.41	.42	.400
C	2	.37	.37	.37	.370
C	3	.68	.75	.76	.730
C	4	.26	.26	.26	.260
C	5	1.27	1.24	1.23	1.250
C	6	.31	.27	.29	.290
C	7	2.5	2.5	2.5	2.500
C	8	.42	.45	.45	.440
D	1	.24	.25	.28	.257
D	2	.166	.166	.166	.166
D	3	.14	.136	.137	.138
D	4	.184	.185	.185	.185

PRESENT ILLUMINATION OF BALCONY

AT 45 DEGREES.

(Continued)

Position of Photometer.		Readings in Candle Feet.			
Section.	Number.	First.	Second.	Third.	Average.
D	5	.157	.148	.145	.150
D	6	.30	.33	.31	.313
D	7	.20	.21	.25	.220
D	8	1.5	1.5	1.5	1.500
D	9	.21	.22	.21	.213
E	1	.095	.097	.096	.096
E	2	.138	.140	.139	.139
E	3	.094	.094	.094	.094
E	4	.134	.138	.136	.136
E	5	.077	.080	.079	.079
E	6	.190	.192	.191	.191
E	7	.063	.066	.064	.064
E	8	.21	.21	.20	.207
E	9	.29	.31	.30	.300
F	1	.22	.23	.24	.230
F	2	.33	.35	.34	.340
F	3	.23	.23	.23	.230
F	4	.58	.62	.60	.600
F	5	.26	.23	.24	.245
F	6	.40	.43	.43	.420
F	7	.44	.46	145	.450
G	1	.18	.19	.18	.183
G	2	.32	.34	.35	.340

PRESENT ILLUMINATION OF BALCONY

AT 45 DEGREES.

(Continued)

Position of Photometer.		Readings in Candle Feet.			
Section.	Number.	First.	Second.	Third.	Average.
G	3	.20	.21	.23	.215
G	4	.62	.60	.61	.610
G	5	,20	.20	.20	.20
H	1	.50	.54	.53	.525
H	2	.34	.34	.34	.340
H	3	.87	.90	.89	.885
H	4	.35	.38	.36	.365

PRESENT ILLUMINATION OF BALCONY

VERTICAL.

Position of Photometer.		Readings in Candle Feet.			
Section.	Number.	First.	Second.	Third.	Average.
A	1	.55	.58	.56	.567
A	2	.44	.48	.50	.473
A	3	.30	.38	.37	.350
A	4	.40	.42	.44	.420
A	5	.38	.43	.41	.407
B	1	.56	.53	.50	.530
B	2	.40	.42	.41	.410
B	3	.40	.42	.38	.400
B	4	.41	.40	.40	.403
B	5	.38	.36	.38	.373

PRESENT ILLUMINATION OF BALCONY

VERTICAL.

(Continued)

Position of Photometer.		Readings in Candle Feet.			
Section.	Number.	First.	Second.	Third.	Average.
B	6	.36	.35	.34	.350
C	1	.49	.49	.49	.490
C	2	.50	.50	.48	.493
C	3	.39	.43	.41	.410
C	4	.32	.32	.34	.327
C	5	.39	.37	.38	.380
C	6	.28	.30	.31	.297
C	7	.30	.32	.31	.310
C	8	.30	.30	.30	.300
D	1	.40	.36	.44	.400
D	2	.44	.47	.45	.453
D	3	.50	.52	.51	.51
D	4	.29	.31	.30	.300
D	5	.31	.28	.30	.297
D	6	.25	.26	.24	.250
D	7	.24	.26	.25	.250
D	8	.172	.176	.176	.174
D	9	.185	.180	.180	.182
E	1	.42	.35	.35	.372
E	2	.38	.38	.38	.380
E	3	.33	.37	.35	.350
E	4	.33	.33	.33	.330
E	5	.22	.22	.22	.220

PRESENT ILLUMINATION OF BALCONY

VERTICAL.

(Continued)

Position of Photometer.		Readings in Candle Feet.			
Section.	Number.	First.	Second.	Third.	Average.
E	6	.26	.24	.23	.245
E	7	.185	.186	.184	.185
E	8	.280	.28	.27	.277
E	9	.20	.19	.18	.190
F	1	.54	.58	.56	.560
F	2	.52	.54	.54	.533
F	3	.33	.34	.32	.330
F	4	.35	.34	.34	.343
F	5	.25	.25	.25	.250
F	6	.26	.27	.27	.267
F	7	.24	.23	.23	.233
G	1	.55	.58	.56	.563
G	2	.50	.50	.50	.500
G	3	.50	.49	.50	.497
G	4	.56	.62	.60	.593
G	5	.38	.38	.38	.380
H	1	.66	.67	.66	.663
H	2	.56	.50	.54	.533
H	3	.47	.49	.48	.480
H	4	.43	.43	.43	.430

PRESENT ILLUMINATION OF CHOIR LOFT

AND PULPIT. HORIZONTAL.

Position of Photometer.	Readings in Candle Feet.			
	First.	Second.	Third.	Average.
1	.88	.86	.87	.870
2	1.	.9	.96	.953
3	.82	.88	.86	.853
4	1.7	1.7	1.7	1.700
# 5	4.	4.	4.	4.000
6	.88	.92	.89	.895
7	.85	.90	.87	.873
8	1.1	1.06	1.07	1.077
9	.88	.92	.90	.900
10	1.23	1.25	1.24	1.240
# 11	2.9	2.9	2.8	2.87
# 12	6.4	6.6	6.5	6.500
# 13	1.63	1.73	1.7	1.700
14	1.0	1.05	1.02	1.023
15	1.0	1.05	1.1	1.050
# 16	2.0	2.0	2.0	2.000
# 17	3.2	3.4	3.3	3.300
# 18	1.92	1.94	1.92	1.927
# 19	1.0	.95	.97	.973
# 20	.77	.79	.78	.780
# 21	1.18	1.16	1.16	1.167
# 22	.94	.96	.96	.947
23	.62	.66	.65	.643

PRESENT ILLUMINATION OF CHOIR LOFT

AND PULPIT. HORIZONTAL.

(Continued)

Position of Photometer.	Readings in Candle Feet.			
	First.	Second.	Third.	Average.
24	.80	.84	.81	.817
# 25	.70	.72	.71	.710
26	.64	.66	.65	.65
27	.73	.70	.74	.723
28	.76	.84	.82	.807
29	.72	.72	.72	.720

In all positions marked #, the readings were taken directly without any absorbing screen.

PRESENT ILLUMINATION OF CHOIR LOFT

AND PULPIT. AT 45 DEGREES.

Position of Photometer.	Readings in Candle Feet.			
	First.	Second.	Third.	Average.
1	.18	.17	.17	.173
2	.176	.176	.176	.176
3	.47	.48	.49	.480
4	.52	.52	.53	.523
# 5	.9	.9	.9	.900
6	.3	.31	.3	.303
7	.25	.26	.25	.253
8	.45	.46	.46	.457
9	.41	.38	.39	.390
10	.80	.84	.82	.82
# 11	1.87	1.83	1.84	1.847

PRESENT ILLUMINATION OF CHOIR LOFT

AND PULPIT. AT 45 DEGREES.

(Continued)

Position of Photometer,	Readings in Candle Feet.			
	First.	Second.	Third.	Average.
# 12	4.3	4.6	4.4	4.430
# 13	1.52	1.56	1.53	1.537
14	.66	.70	.68	.680
15	1.1	1.1	1.1	1.100
# 16	1.9	1.92	1.93	1.917
# 17	3.4	3.4	3.4	3.400
# 18	2.0	2.0	2.0	2.00
# 19	.9	.9	.9	.900
# 20	.79	.81	.8	.800
# 21	1.23	1.25	1.24	1.24
# 22	.99	.97	.98	.980
23	.74	.76	.76	.753
24	.84	.82	.81	.827
# 25	.68	.68	.68	.680
26	.73	.70	.71	.713
27	.70	.72	.72	.713
28	.66	.67	.66	.663
29	.55	.60	.57	.573

On all positions marked #, the readings were taken without the use of the absorbing screen.

PRESENT ILLUMINATION ON CHOIR LOFT

AND PULPIT. VERTICAL.

Position of Photometer.	Readings in Candle Feet.			
	First.	Second.	Third.	Average.
1	.67	.67	.67	.670
2	1.10	1.1	1.1	1.100
3	.54	.56	.55	.550
4	.8	.9	.85	.850
# 5	1.55	1.53	1.54	1.54
6	.72	.76	.74	.740
7	.66	.68	.65	.663
8	.76	.75	.74	.750
9	.47	.52	.49	.480
10	.28	.28	.26	.273
11	.31	.32	.33	.320
12	.34	.34	.35	.343
13	.39	.41	.40	.400
14	.36	.38	.37	.370
15	.34	.36	.36	.353
16	.32	.34	.33	.330
17	.31	.32	.33	.320
18	.34	.36	.35	.350
19	.27	.28	.28	.277
20	.39	.41	.40	.400
21	.48	.52	.51	.503
22	.37	.39	.37	.377
23	.37	136	.35	.360
24	1.4	1.3	1.36	1.363

PRESENT ILLUMINATION OF CHOIR LOFT

AND PULPIT. VERTICAL.

(Continued)

Position of Photometer.	Readings in Candle Feet.			
	First.	Second.	Third.	Average.
25	.38	.39	.37	.380
26	.40	.41	.42	.410
27	.42	.42	.42	.420
28	.44	.49	.46	.463
29	.29	.30	.30	.297

On all positions marked #, the readings were taken without the use of the absorbing screen.

RESULTS OBTAINED BY CALIBRATING THE

ABSORBING SCREEN.

	Readings in Candle Feet.				Absorbtion.
	First.	Second.	Third.	Average.	%
With Screen.	12.4	11.8	12.3	12.17	
Without Screen.	1.21	1.20	1.22	1.21	10.06
With Screen.	14.2	14.5	14.5	14.4	
Without Screen.	1.44	1.44	1.47	1.45	9.93
With screen.	8.8	8.7	8.5	8.66	
Without Screen.	.89	.86	.82	.856	10.14
				Average.	10.04

CALCULATIONS SHOWING ILLUMINATION ON A POINT DIRECTLY BELOW THE CENTRAL CEILING LAMP OF THE NEW DESIGN.

From lamps extending from side to side.

Distance from center - ft.	Angle.	Cos^3	C. P.	I ft. candles.	Total I ft. candles.
3	6	.983	35	.0408	
6	11-30	.950	37	.0418	
9	17-30	.867	35	.0360	
12	22-30	.788	32	.0300	
15	27-15	.702	29	.0242	
18	31-45	.615	27	.0198	
21	36	.529	24.5	.0155	
24	39-45	.454	22.2	.0120	
				.2201	
			Sameon the other side	.2201	
				.4402	.4402

From lamps extending from front to back.

3	6	.981	35	.0410	
11	21	.813	33	.0320	
19	33	.590	25	.0175	
				.0905	
			Same on the other side	.0905	.1810

From 200 watt center lamp.

0	0	o	256	.305	.3050
					.9262

A COMPARISON OF THE COSTS OF THE OLD AND NEW SYSTEMS.

Present System.		New Design.	
Candle power needed;		Candle power needed;	
70 - 16 C.P. carbon lamps -	1120	3 - 32 C.P. carbon -	100
1 - 100 watt tungsten -	80	1 - 16 C.P. "	16
Candle Power	1200	55-25 watt tungsten	1100
		1 - 200 " "	160
		Total	1376

First Cost.		First Cost.	
70-16 C.P. lamps at .16-	$12.00	55-25 watt tungsten at .70-	$39.50
1 - 100 watt tungsten	1.50	1 - 200 watt tungsten	2.00
Total	$13.50	3 - 32 C.P carbons at.35	1.00
		1 - 16 " " at.17	.17
		Total	$42.67

Life.	Life.
500 hours.	500 hours with frosted bulbs.

Power used during life assuming 3.5 watts per C.P. for carbon lights and 1.25 watts per C.P. for tungstens.

Carbons 3.5 x 1120	3920	Carbons 3.5 x 100	350
Tungsten	100	Tungstens	1570
	4020		1920

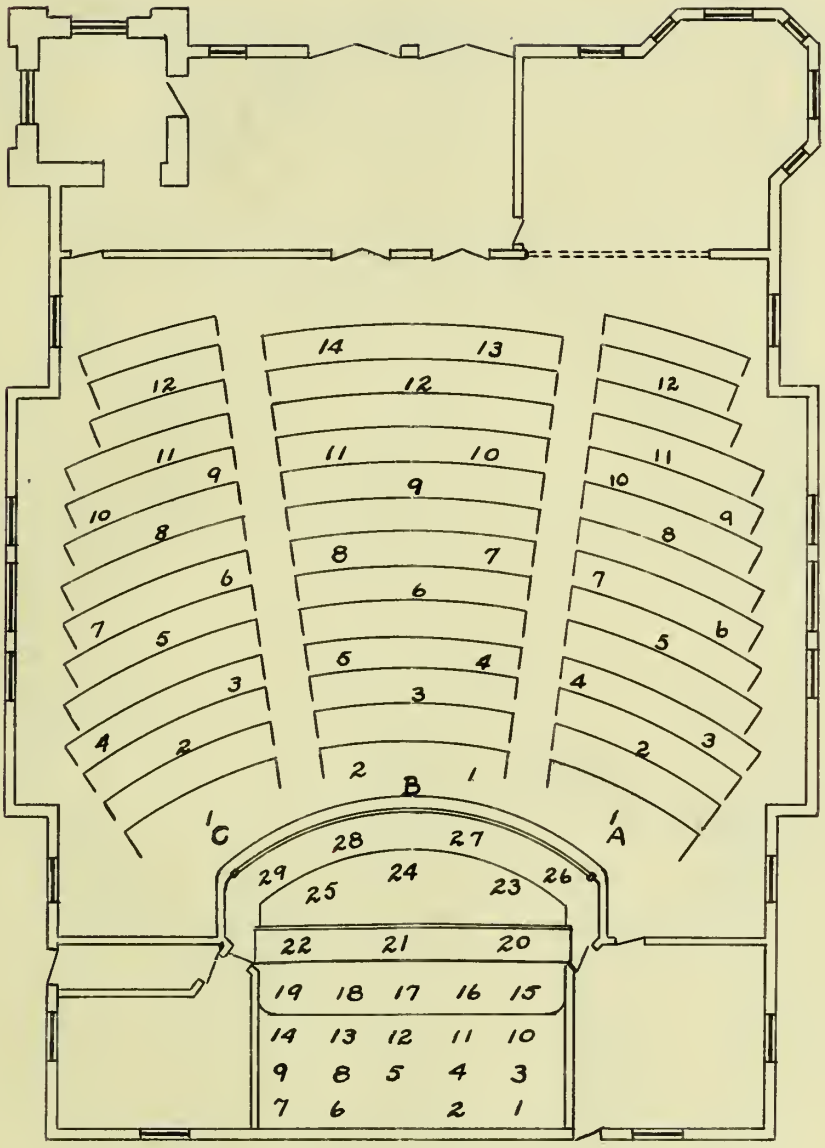
Cost of power for each assuming life of 500 hours for each and power to cost $.10 per K.W hour.

4020 x 500 x .10	$201.50	1920 x 500 x .10	$96.00

A Comparison of the Costs of the Old and New Systems.

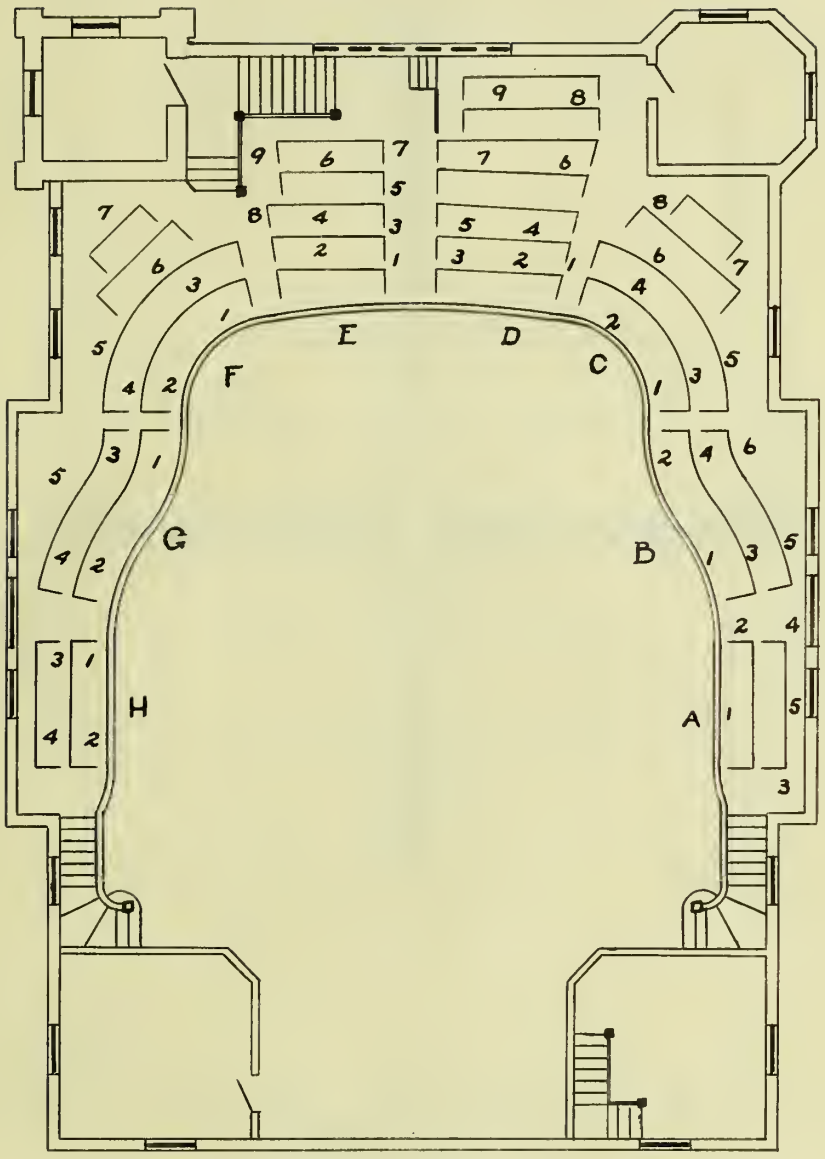
Summary.

	Candle Power.	First Cost.	Life hrs.	Power used during life.	Cost of power.	Total cost.
Old System.	1200	$13.50	500	4020	201.50	215.00
New System.	1376	42.67	500	1920	96.00	138.67



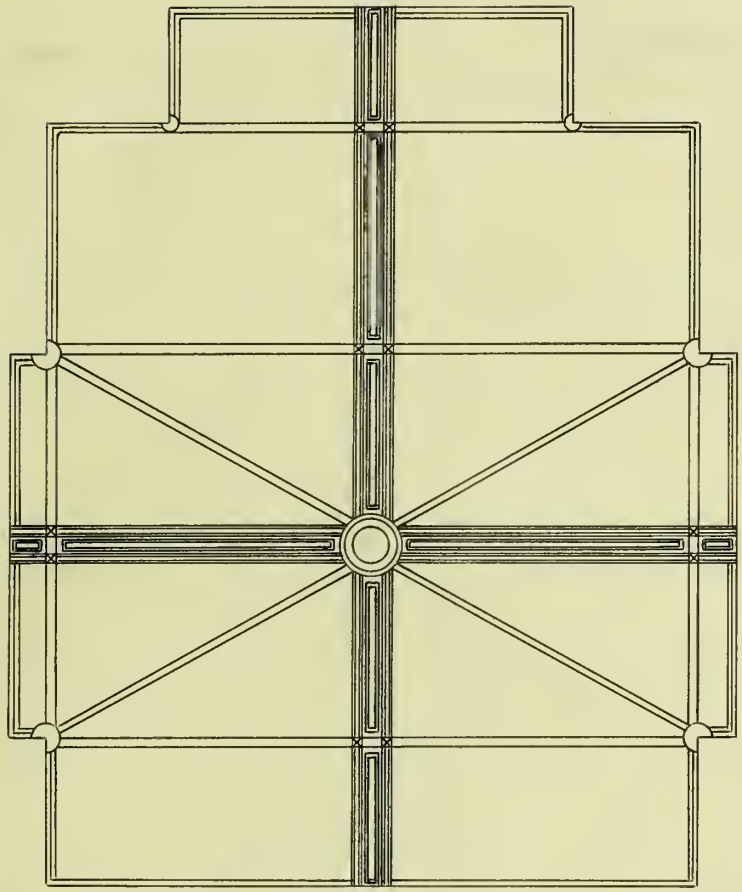
Main Floor.

REFERENCE POINTS TO DATA.



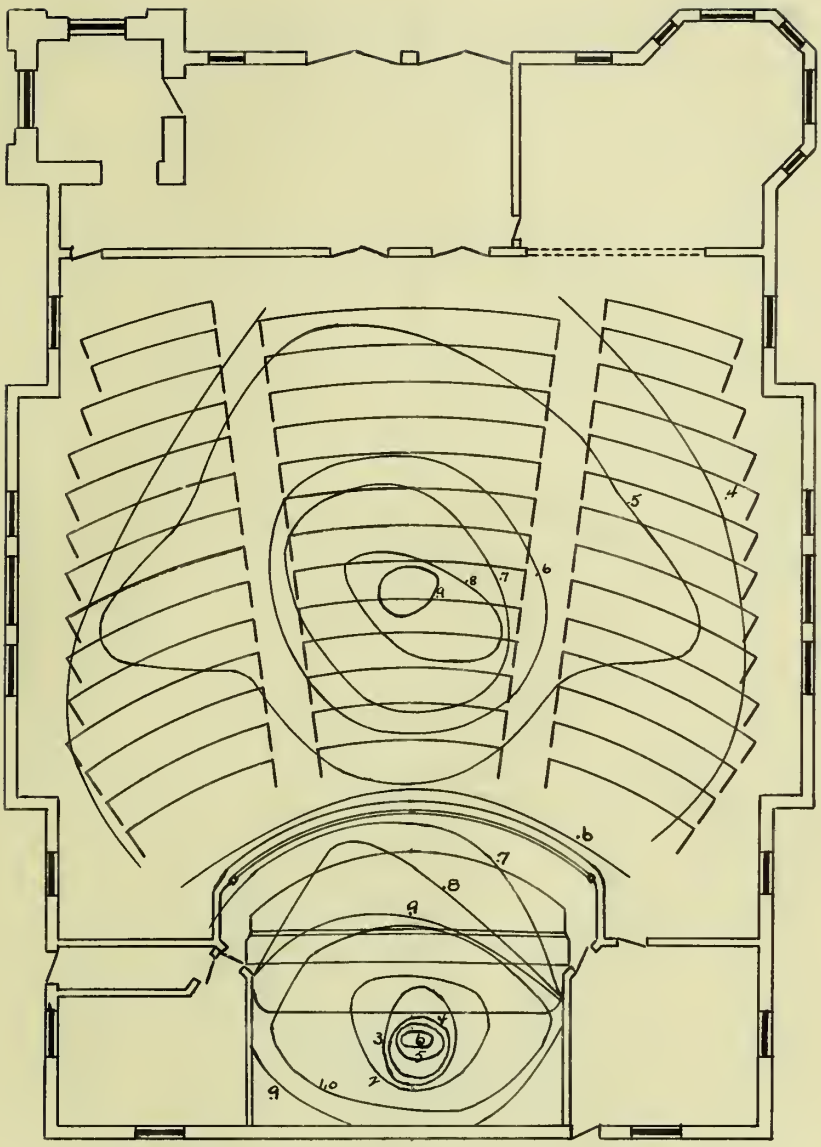
Balcony.

REFERENCE POINTS TO DATA.



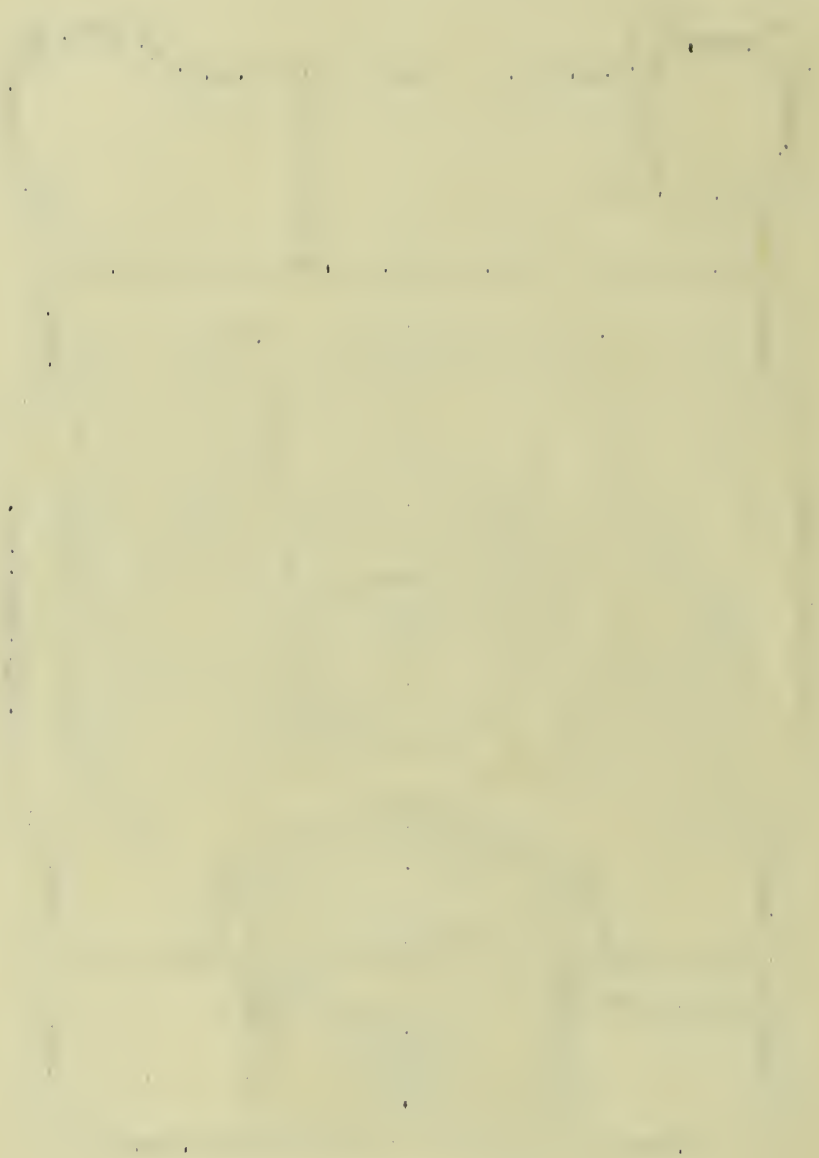
Ceiling.

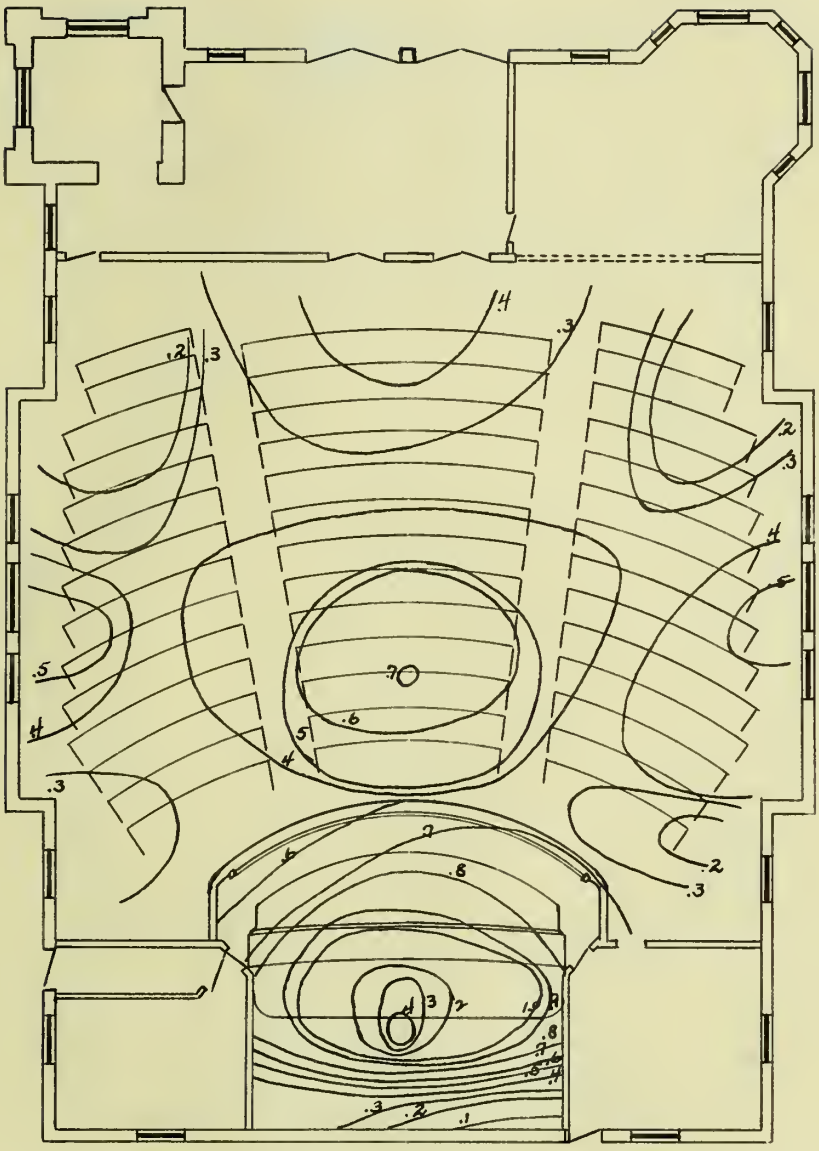
SHOWING GIRDERS ON WHICH NEW LAMPS ARE PLACED.



Main Floor.

CURVES OF EQUAL HORIZONTAL ILLUMINATION.
Foot - Candles.

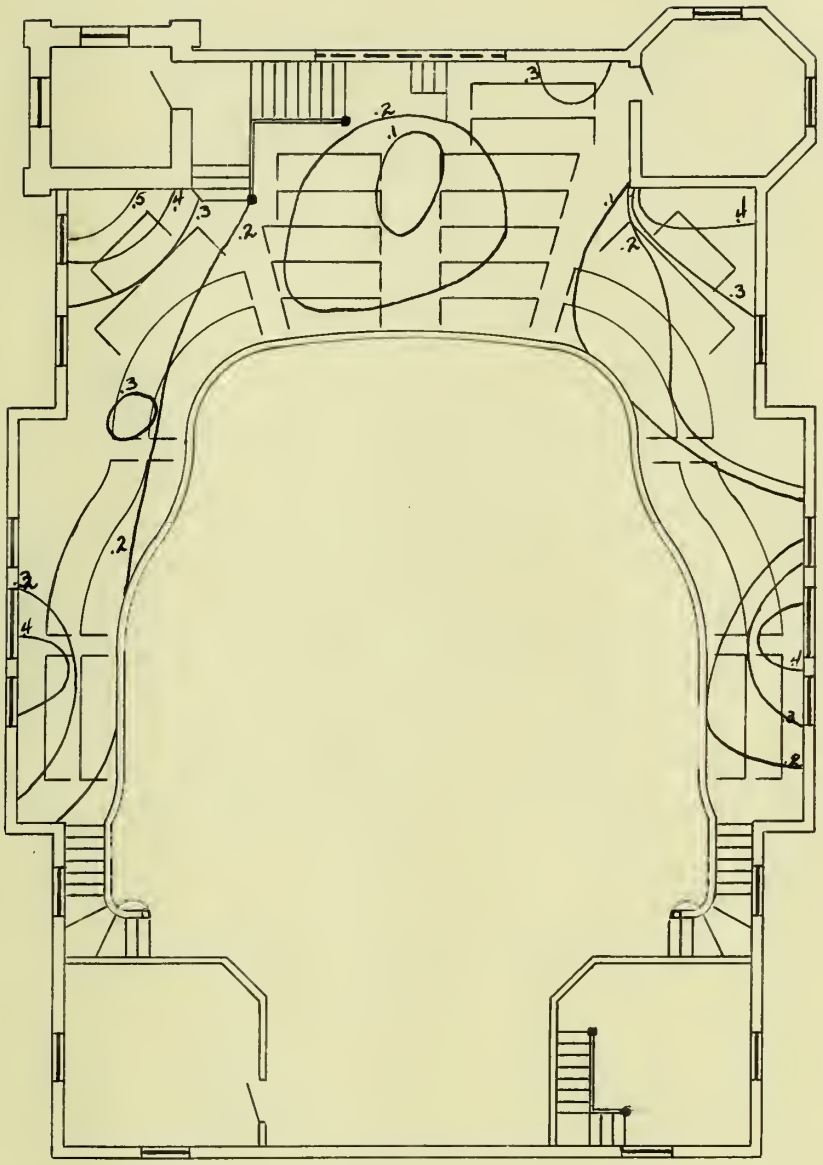




Main Floor.

CURVES OF EQUAL 45° ILLUMINATION.

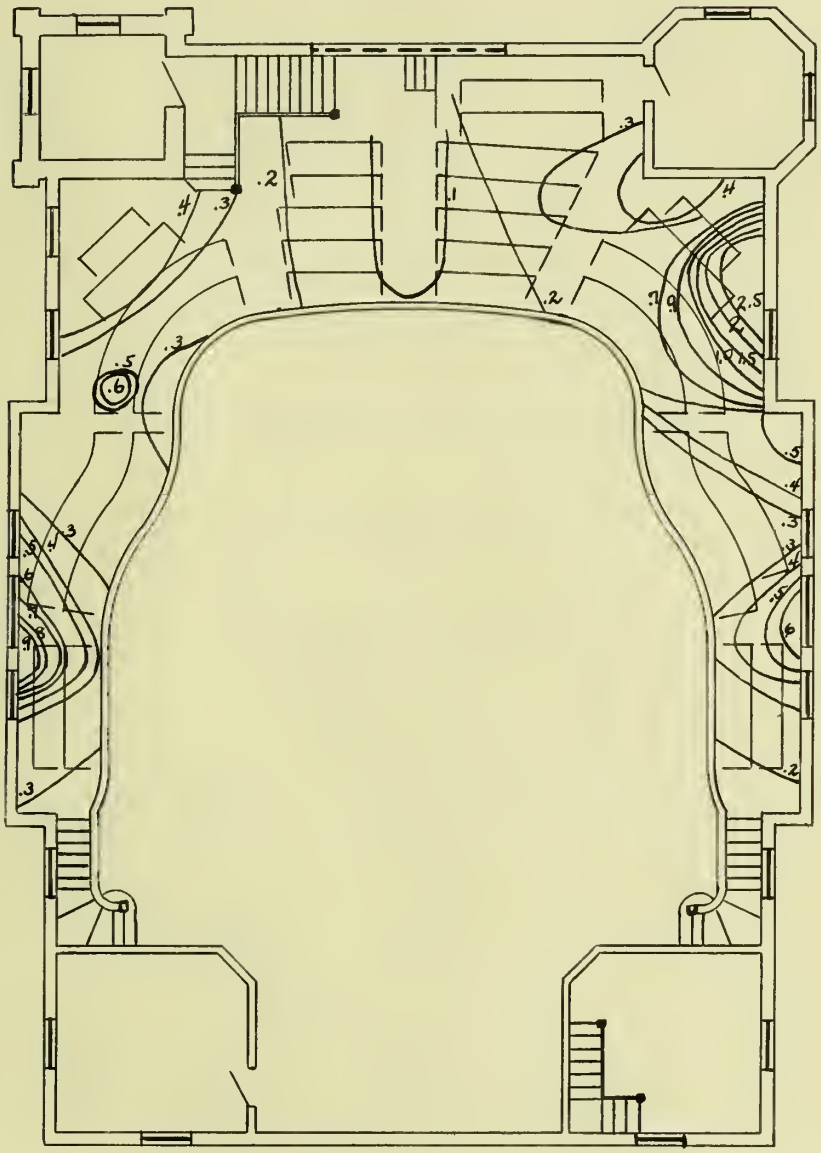
Foot - Candles.



Balcony.

CURVES OF EQUAL HORIZONTAL ILLUMINATION.

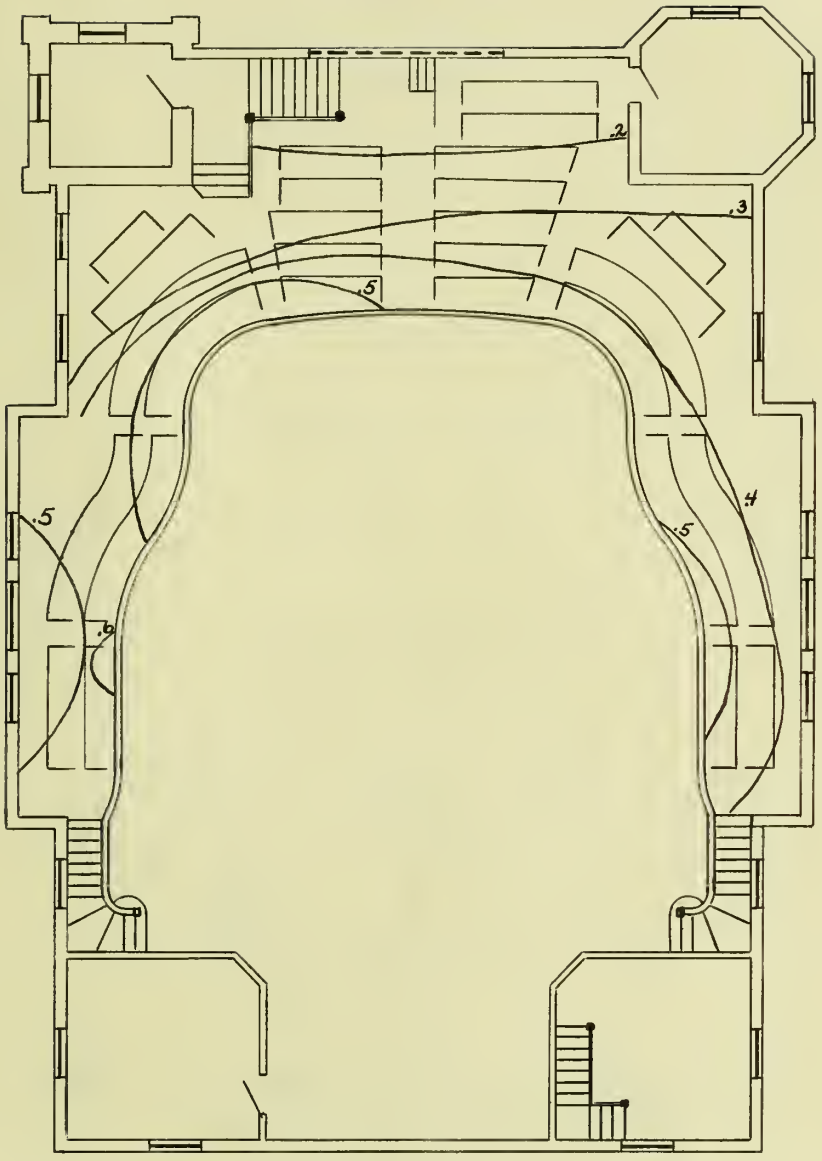
Foot - Candles.



Balcony.

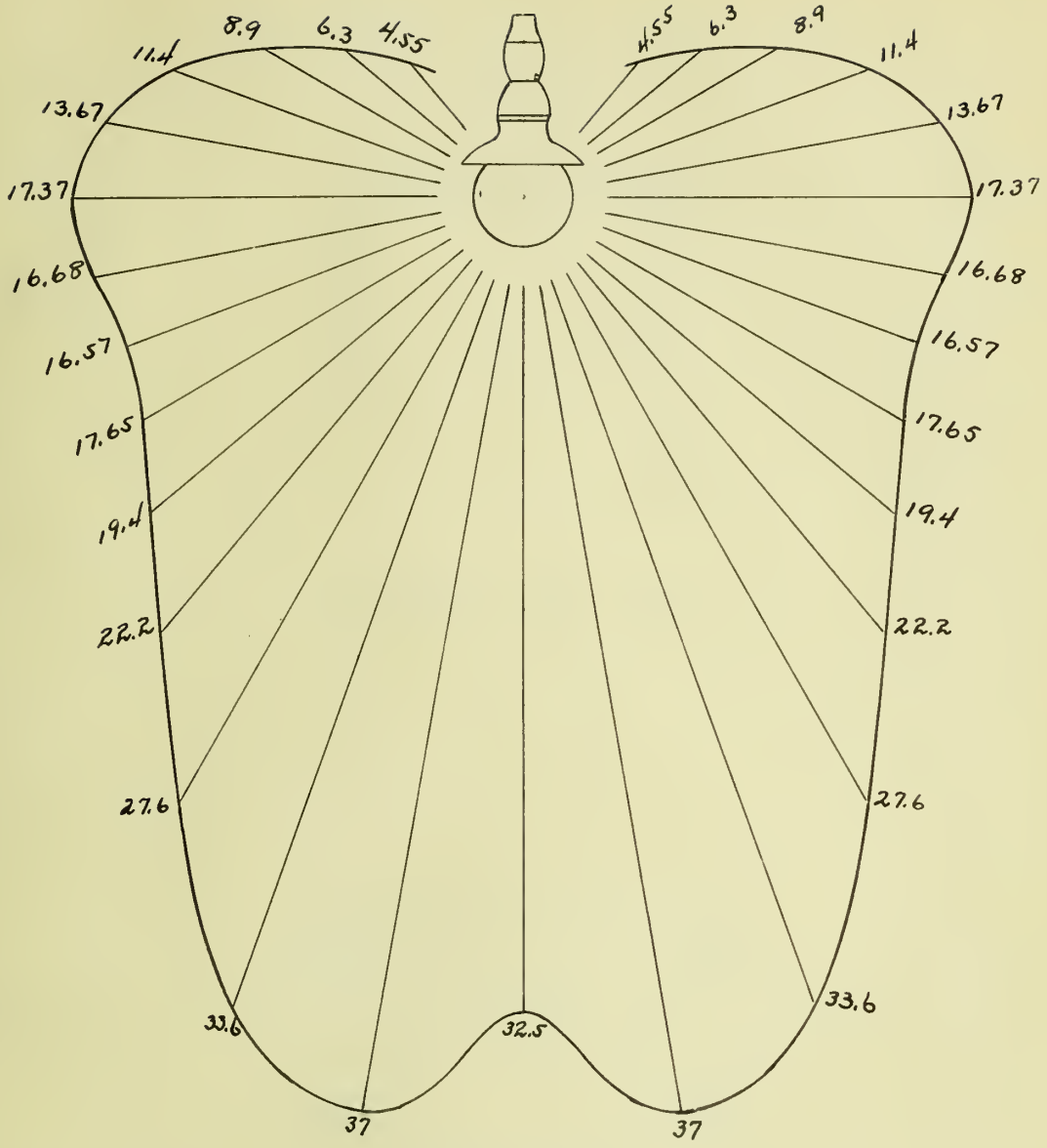
CURVES OF EQUAL 45° ILLUMINATION.

Foot - Candles.

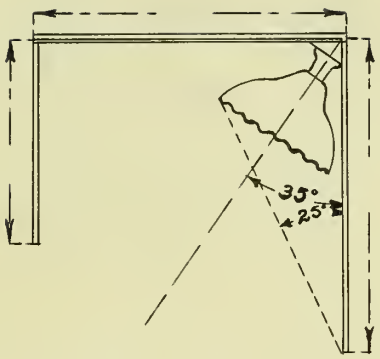


Balcony.

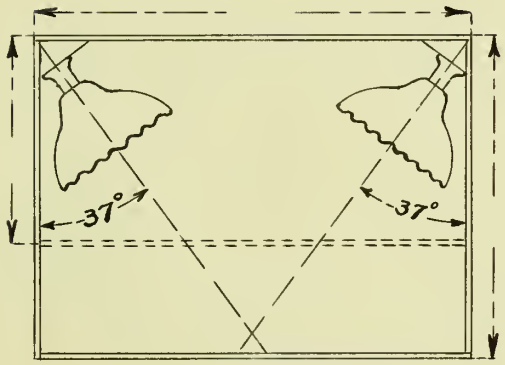
CURVES OF EQUAL VERTICAL ILLUMINATION.
Foot-Candles.



LIGHT ABOUT 25-WATT MERIDIAN LAMP WITH PRISMATIC REFLECTOR.

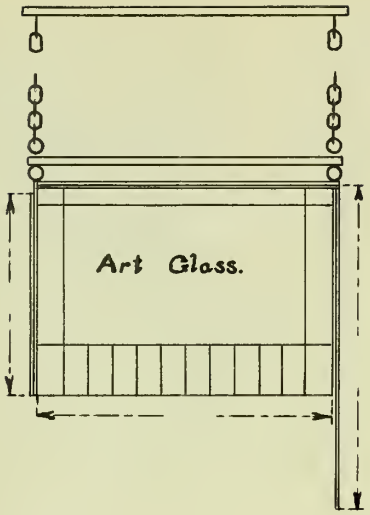


Sectional Side View.

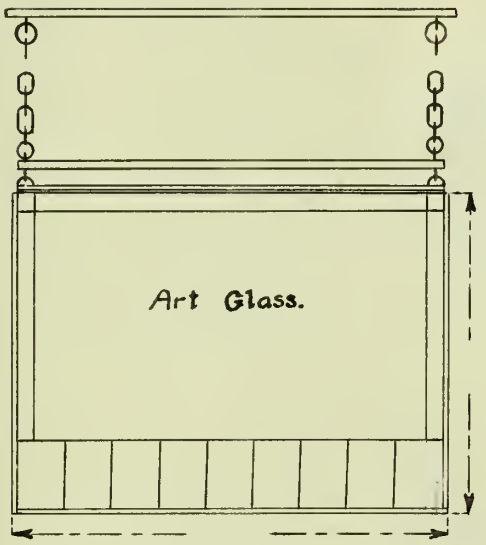


Sectional Rear View.

ART GLASS FIXTURE FOR CHURCH LIGHTING.



Side View.



Rear View.

ART GLASS FIXTURE FOR CHURCH LIGHTING.